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Invited Paper

Recent Advances of Color Plasma Displays

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Abstract

Several kinds of color PDPs have been converged to a single group of the surface-discharge color ac PDPs of which the reason will be described on the basis of the recent advanced ultraviolet-rays measuring systems.

PDP Manufacturers completed to construct the first generation of mass production lines for color PDPs and now doing to accomplish the second generation of ones until 2001. Under the existing circumstances in Japanese PDP manufactures one of the most distinctive events in 1999 is amalgamating or cooperative motions between PDP manufacturers within or outside of Japan.

The present paper will also describe the latest information about the processes and materials of which composed the advanced color PDPs.

1. Introduction

During the past several years, 20-inch to 50-inch diagonal color PDPs have become available commercially and LG and Plasmaco tried to fabricate 60-inch diagonal ones to demonstrate them at the exhibition. On the basis of these accomplishments, manufacturers have now almost constructed the first generation of mass production of color PDPs and commercialized them, and recently *Fujitsu Hitachi Plasma Display* (*FHP*), *NEC*, and *Pioneer* are constructing the second one, which are attracting a great deal of attention.

The system structure and design stage for the first generation of color PDPs are now over, and a mass production process, which can achieve a high yield and throughput, is being sought. As more manufacturers enter the color PDP production field and attempt to develop innovative technologies on the basis of new concepts for device materials and components, the manufacturing processes and the trend of color plasma display industry, in particular, in Japan are being reviewed.

Even though the surface-discharge electrode configuration has the excellent performance essentially, their performance must be improved to be used for the advanced computer monitors and the High-Definition TV. The recent distinctive results in the improvement of performance are ALIS by *Fujitsu*, Waffle structure and CLEAR (Hi-Contrast & Low Energy Address & Reduction of False Contour Sequence) operating scheme by *Pioneer*, and the full-scale High-Definition TV monitor by *Panasonic*, respectively. The specifications of Fujitsu are 500 cd/cm^2 and 250 W for 42-inch diagonal with 1,024 $\times$1,024 pixels. Those of Pioneer are 560 cd/cm^2 and high contrast ratio of 560:1. Those of Panasonic are very fine resolution of 1,920 $\times$1,080 pixels and very high contrast ratio of 300:1 for 42-inch diagonal one.

2. Color PDPs Market in Japan

It is pointed out that luminance of 500 cd/m^2 achieved by ALIS is evaluated to be acceptable value for home use TV. *Sony* will deliver color PDP TV receivers by purchasing ALIS from Fujitsu this year.

Under these circumstances, it is speculated that a maximum production volume of color PDPs in *Fujitsu*, *NEC*, and *Pioneer* in 1999 are 10,000, 10,000, and 4,000 units per a month, respectively. It is also speculated that total sales volume of color PDPs produced in Japan is a half of maximum production volume, that is, 12,000 units per a month. The selling amount of color PDPs in 1998 and 1999 are 500 and 1,500 million dollars, respectively and in 2002 it will be reached to 1 billion dollars after the present construction of the second stage manufacturing process lines will be completed. It is well known that a half volume of color PDPs are sold in Europe.

3. Current Status of Color PDP Developments

The 21-inch diagonal full-color ac-PDPs commercialized by *Fujitsu* in 1993 were the first to be used as television monitors. *Fujitsu*, *NEC*, *Pioneer*, *Mitsubishi Electric*, *Panasonic*, and *Hitachi* tried to being manufacturing or establishing to manufacture 40 to 50-inch diagonal full-color ac-PDPs.

Overseas, *Thomson CSF* is working on two-substrate electrode structure, while *Plasmaco* has adopted the surface-discharge electrode structure that is exactly identical to that of Fijitsu products. In the U.S. *Plasmaco* has developed 60-inch full-color ac-PDPs and demonstrated it at 1999 SID Symposium and Exhibition. In France, *Thomson CSF* has successfully developed high-definition PDPs with discharge cell pitches of 0.125 nm, and realized a 19-inch diagonal

XGA (1,024 ×RGB ×768 dot) display.

In the Asia region outside of Japan, *LG*, *Samsung*, and *Orion* and *Acer* and *CPT* are constructing mass production lines in Korea and Taiwan, respectively.

4. Operation Mechanisms of Color PDPs based on the Advanced Experiments using Ultraviolet Rays Measuring Systems

It has seemed to be very strange for us that luminance and luminous efficiency of color PDPs are larger than those of monochrome PDPs. The advanced experiments solved this strangeness based on the measured results that the ultraviolet rays emitted from Xe and Xe dimers are distrubuted simultaneously around both the cathodes and the anodes; neon orange color emission from Ne is limited around only the cathodes. Based on these experimental results, roughly speaking, luminance and luminous efficiency of color PDPs is two times larger than those of monochrome ones.

The computer simulation confirms the recent experimental results of simultaneous ultraviolet rays emission from both the cathodes and the anodes. The studies on the experimental and simulated results make remarkable progress on understanding the basic gas discharge phenomena generated in color PDPs. It is also expected that the experimental and simulated results contribute to improve performance of color PDPs, in particular, luminance and luminous efficiency.

5. Future Issues of Color PDPs Including Production of PDP Barrier Ribs and Phosphors

To understand the issues of color PDPs to be solved in the future, the electrode structure full-color ac-PDP is described below. On the rear glass substrate, address electrodes and barrier ribs are formed by baking, providing a discharge space for the prevention of optical cross talks.

The barrier ribs are approximately 50μm wide and about 100μm tall. RGB phosphors are printed on the address electrodes and rib sides, forming one pixel to each set of RGB phosphors. A Ne+Xe (4%) Penning mixture gas at the pressure of 600 Torr is used as the filling gas.

The barrier ribs for 20-inch diagonal PDP are produced by the thick-film screen printing method. Although thick-film printing technology has advanced, the production of barrier ribs is expected to be the technological hurdle in the production of PDPs of 40-inches or larger. In this environment, the sandblast method [2][3] and dry film method [4] are attracting attention as potential replacements for thick-film printing. The sandblast method is used in Fujitsu's 42-inch color PDPs. [5] This method is based on photoresist processing and can produce barrier ribs of 50 μm in width for the production of fine patterns.

Attempts have recently been made to incorporate photosensitivity into the insulating paste that forms the ribs themselves for discharge. In principle, the sandblast and dry film methods are advantageous for the production of fine patterns using photolithography. They, however, require a further process after the rib formation photoprocess. If the insulating material, which itself forms ribs, has photosensitivity, ribs can be formed by a single photoprocess.

One of the most advanced example is photorithograpic technology to apply the fabrication color PDP with a performance for full-spec High-Definition specifications by *Panasonic.*

Color PDPs use the photoluminescence phenomenon induced by vacuum ultraviolet rays, as in the case of fluorescent lamps. Development has been advanced by improving the characteristics of the phosphors used in CRT for Red, Green, and Blue. (Y,Gd) $BO_3:Eu^{3+}$ for Red, $Zn_2SiO_4:Mn$ for Green, and $BaMgAl_{14}O_{23}:Eu^{2+}$ for Blue, have been used. However, since $Zn_2SiO_4:Mn$ has a long afterglow, $BaAl_{12}O_{19}:Mn$ has recently been used for Green.

6. Systems for Achieving High Luminance and Luminous Efficiency and Future Issues

The most important issue to be tackled to promote the application of color PDPs in practical products is the improvement of luminance and luminous efficiency. In ac-PDPs that use the surface-discharge electrode configuration represented by *Fujitsu* products, the reflective structure is used. In this system, the light emitted from the phosphor surface of the rear substrate is obtained through the transparent electrodes formed on the surface substrate. This system has achieved twice the luminance of conventional transmissive formats in which light transmitted through phosphors is obtained. The application of phosphors deposited on the barrier rib sides also contributes to the improved luminance.

High luminance and high luminous efficiency have been achieved by adopting a surface-discharge electrode structure and phosphor reflection system. 21-inch diagonal PDPs with a life of more than 30,000 hours, and 200 cd/m^2 luminance and 0.7 lm/W luminous efficiency, have been achieved. [6]

A discharge cell of about 0.3 mm is used to form a pixel of 0.9-10 mm in 40-inch diagonal or larger PDP displays, and 42-inch diagonal models a luminance of 350 cd/m^2 and a luminous efficiency of 1.2 lm/W have been achieved using T shaped electrode structure with discharge cells of this size. [7] However, 17 to 20-inch diagonal models, which require smaller discharge cells, must be developed for workstations that accommodate multimedia applications.

In order to improve luminance and luminous efficiency of the surface-discharge ac color PDPs with a fine resolution,

Fujitsu proposed the ALIS (Alternate Lightning Surfaces) Method. ALIS is able to be operated almost two times finer resolution, that is SXGA, even the cell pitch of VGA. The basic operation mechanisms of ALIS is interlace operation in which pairs of row sustaining electrodes are addressed. From this reason, resolution increases two times finer with keeping the same resolution as VGA.

The 42-inch diagonal SXGA surface- discharge ac color PDP operated by ALIS accomplishes the remarkable achievements of luminance of 500 cd/m^2 and low power consumption of 250 W. These specification will be improved as luminance of 700 cd/m^2 and less than 200 W within a year. When these specifications will be accomplished, real home PDP TV will be commercialized in the near future.

7. Image Quality of Color PDPs for TV Monitor

Until recently, there was concern that the false contours generated by the use of the sub-flame modulation method for producing color PDP gradations may have become a bottleneck in the use of PDPs in TV display monitors. Technological advances in this field, however, have almost eliminated the problem of false contours, securing the future of color PDP TV monitors. [8]

It is important for color PDPs to increase luminance and luminous efficiency by new operation principle and electrode structure. *Panasonic*, however, shows that variable cell structure and new driving system called the Plasma AI (*A*daptive brightness *I*ntensifier)[9] are also very effective to improve performance of color purity and reducing power consumption, respectively.

8. Conclusions

There is a great deal of interest in color PDPs for use in TV or multimedia displays, and in particular, large ones that exhibit excellent characteristics. As a result, color PDPs have achieved superiority over other kinds of display in the field of 1m diagonal color displays.

On the basis of the achievements in the 1 m diagonal screen described in the present paper, further improvements are expected in basic structure, characteristics, device materials, driving systems, and manufacturing technology, targeting from 50 cm to over 1 m-diameter color PDPs that accommodate SXGA displays.

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